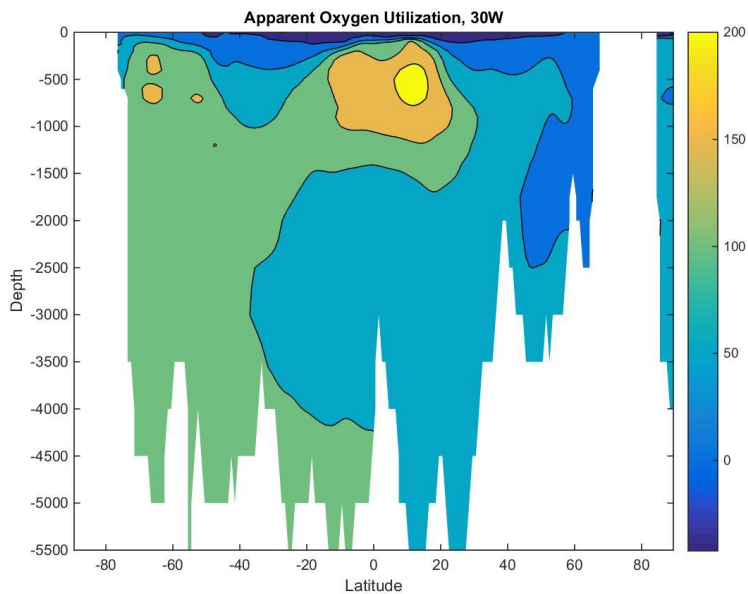
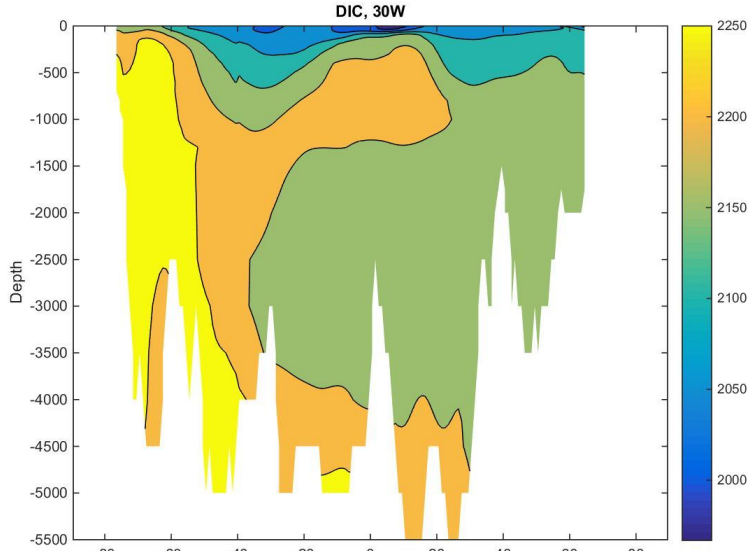


Biogeochemical responses to the ozone hole

Anand Gnanadesikan
FESD Summer Meeting
Cambridge, June 2016

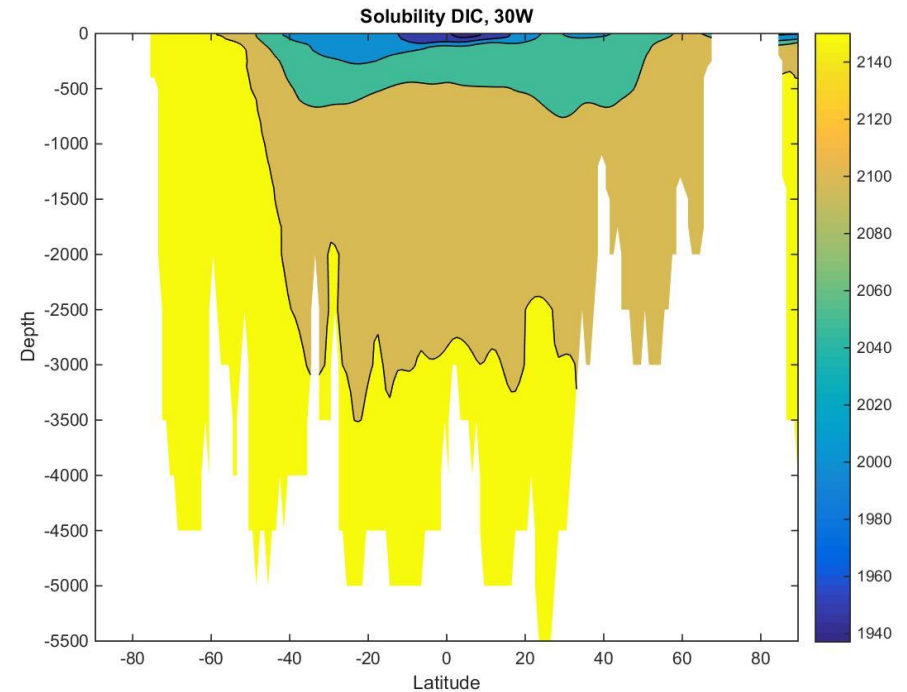
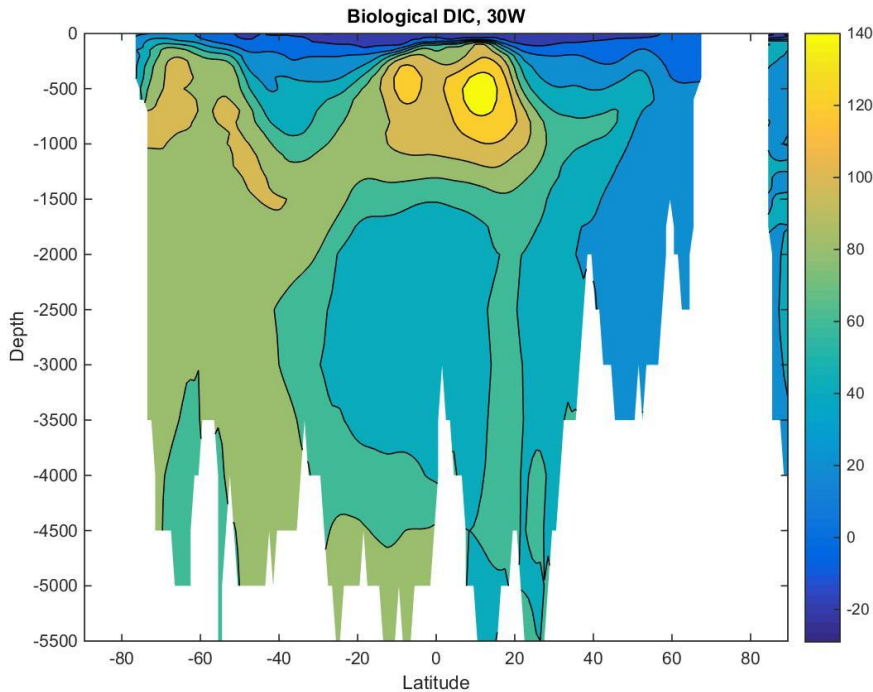
Background on carbon pumps



Deep ocean holds more carbon than surface ocean for two reasons.

1. Solubility pump- cold waters hold more DIC.
2. Biological pump, organic material falls to depth and is remineralized into inorganic nutrient. This process also consumes oxygen.

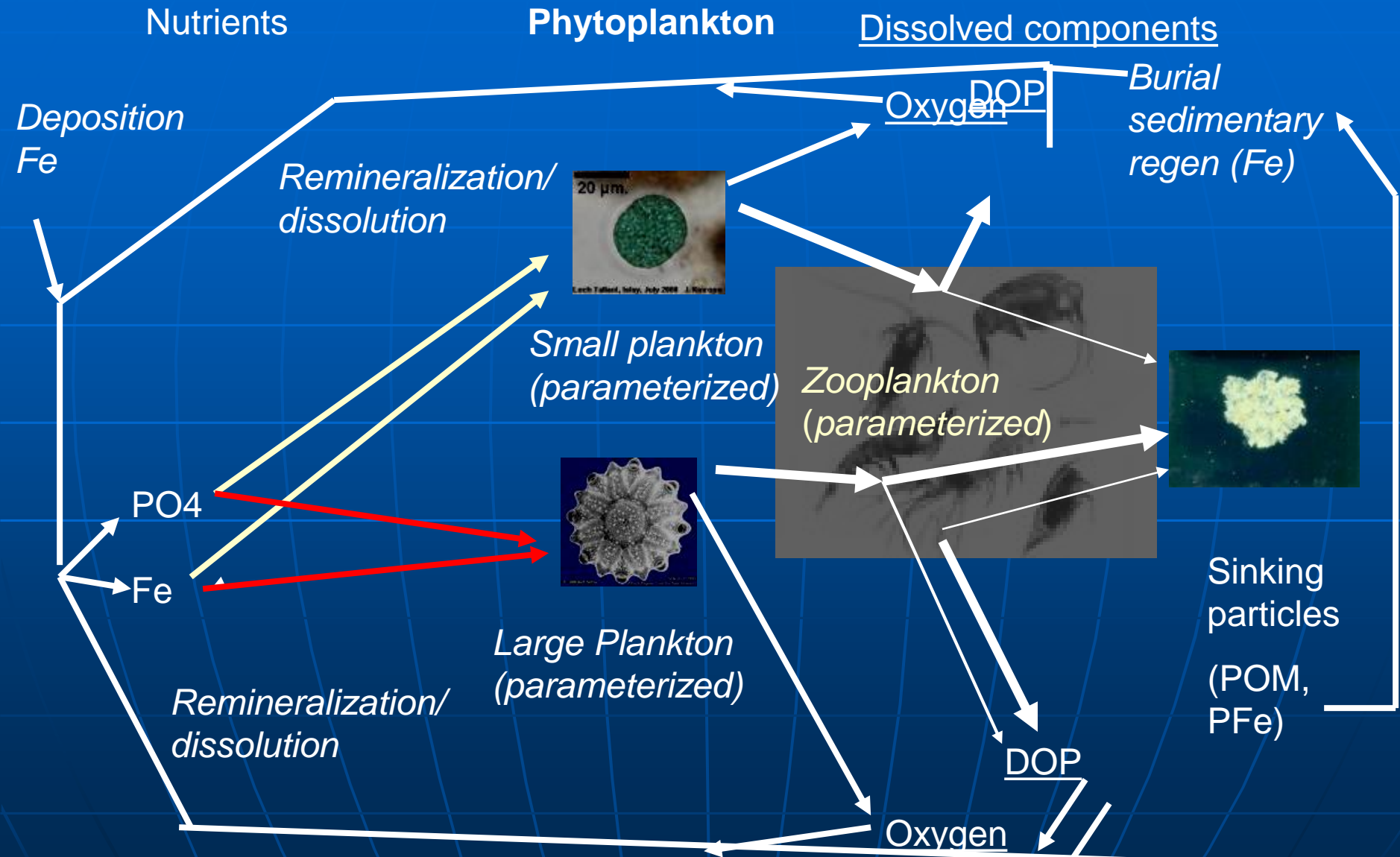
Decomposing the pumps



Biological: estimated from ratio of AOU to DIC

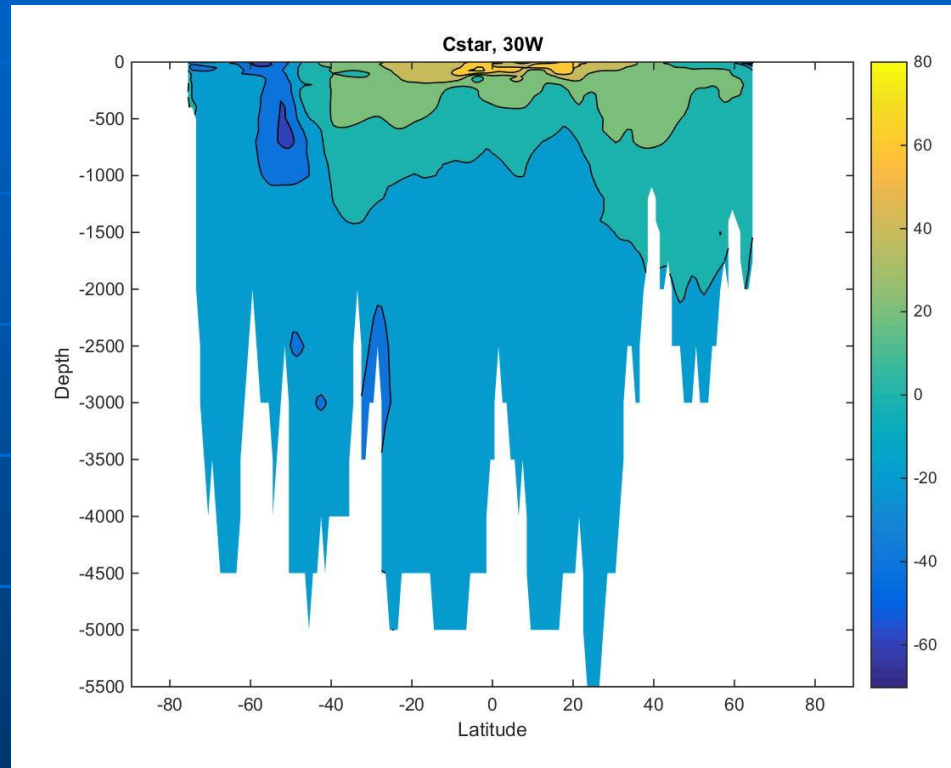
Solubility: Value in equilibrium with preindustrial $p\text{CO}_2$.

A simplified biogeochemistry model (BLING)



To compute anthropogenic carbon: Step 1...

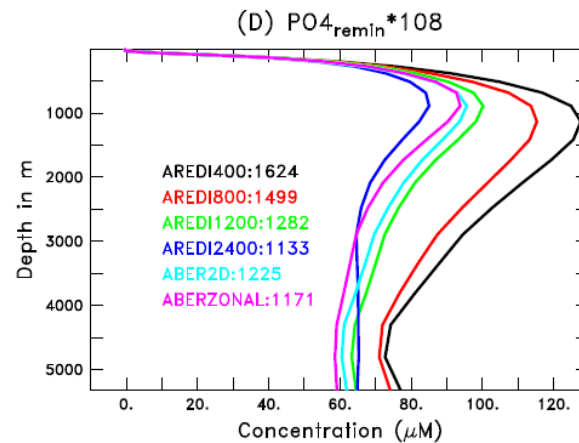
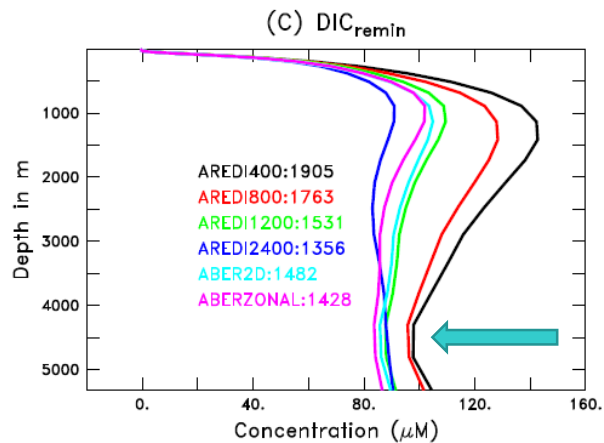
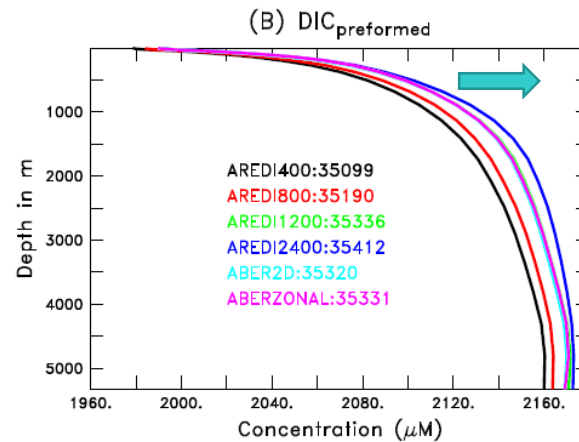
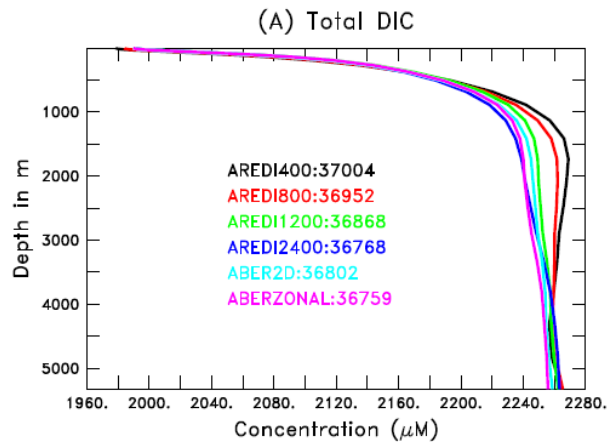
- Generally focus is on solubility.
- Remove preindustrial carbon
- Remove biological pump, remineralized calcium carbonate-*assume these are constant*



Note negative values...
Significant corrections need to be applied.

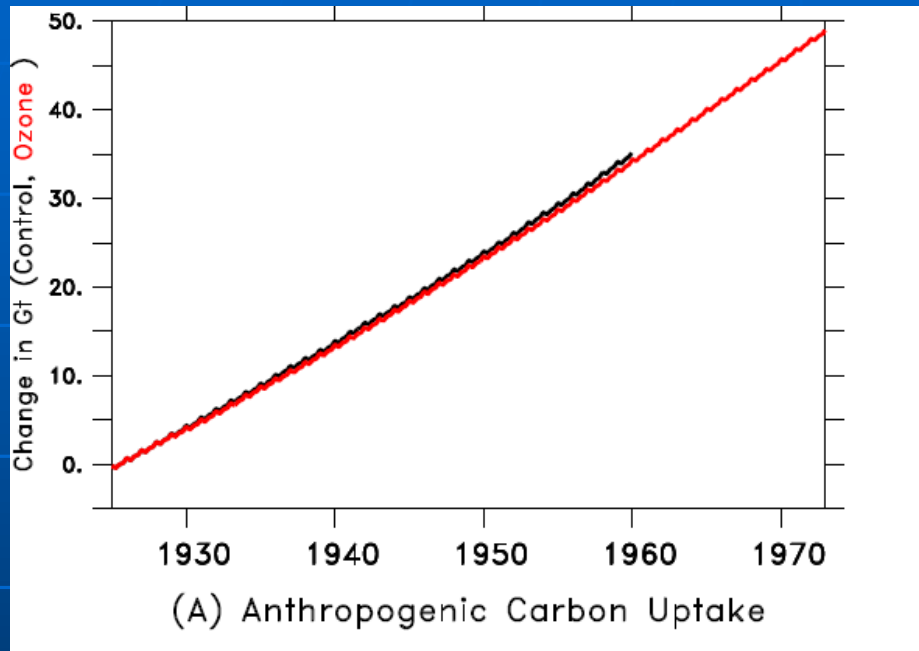
How do these pumps change as circulation changes?

Solubility:
Increases as
SO
ventilation
increases



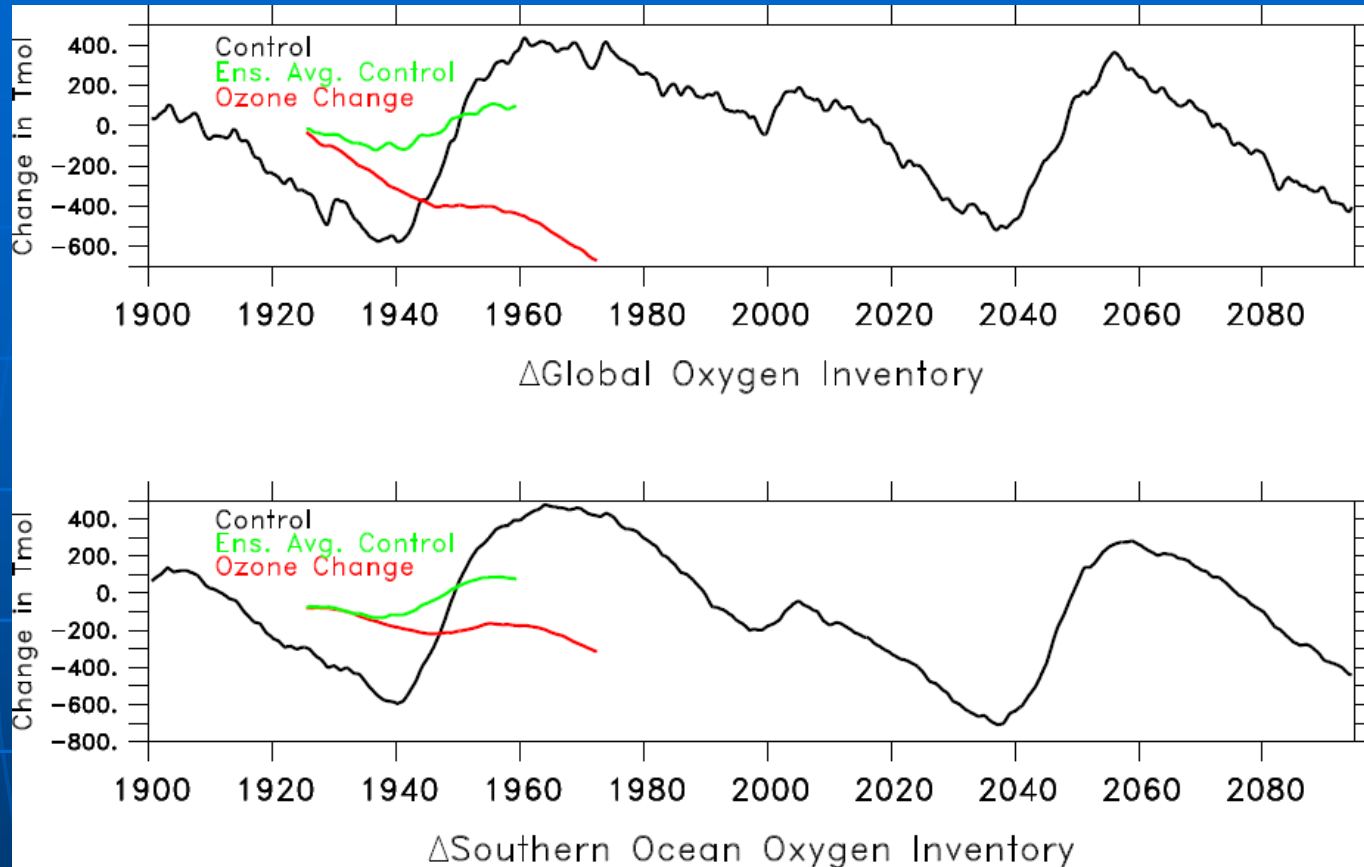
Biological: Decreases as SO ventilation increases.
Gnanadesikan, Pradal and Abernathey, rev. for GBC

Carbon uptake with and without ozone hole



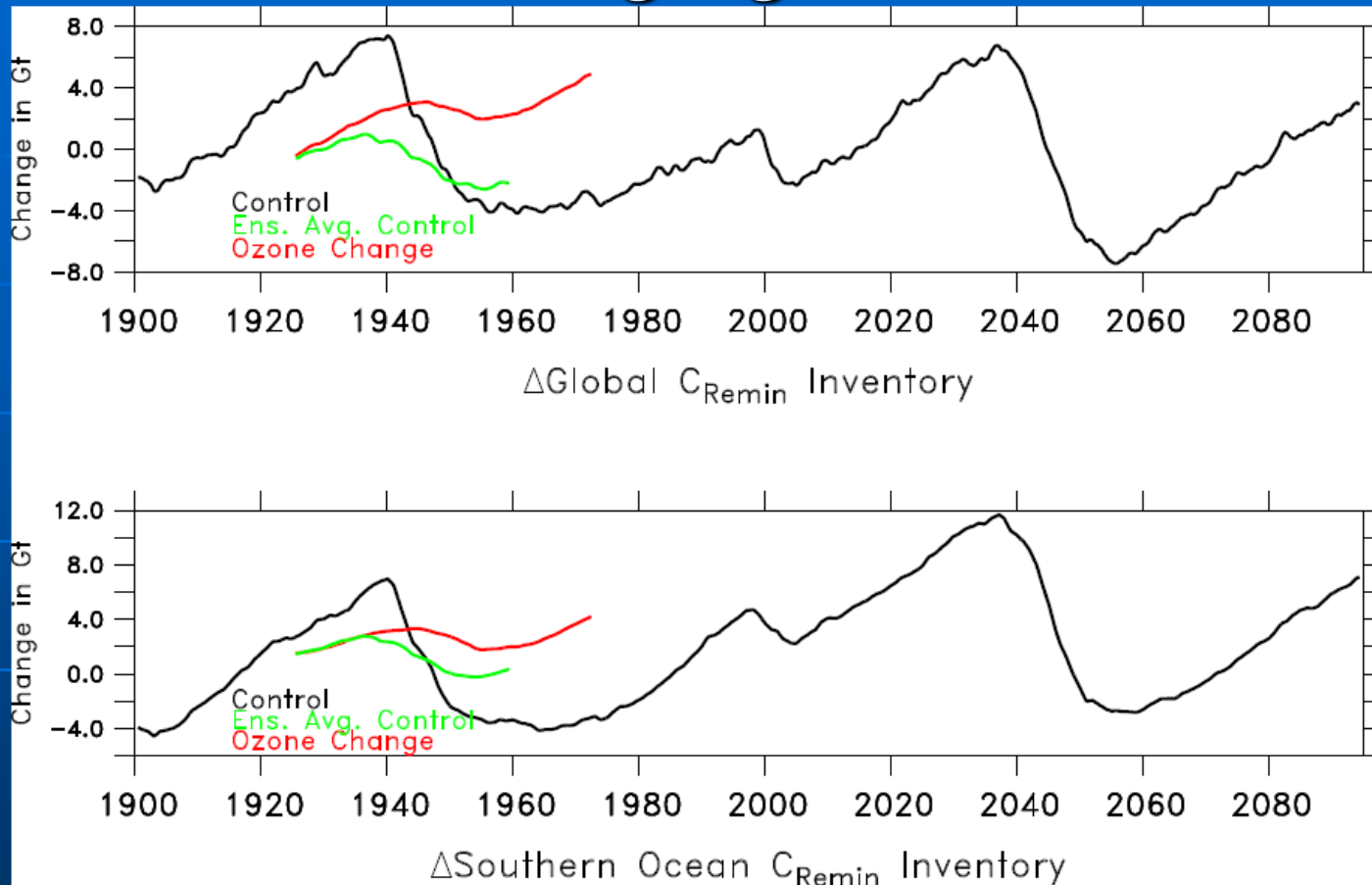
- Response over 35 years is small- a decline of about 3% of total change.
- What about other tracers?

Response of oxygen to changing ozone



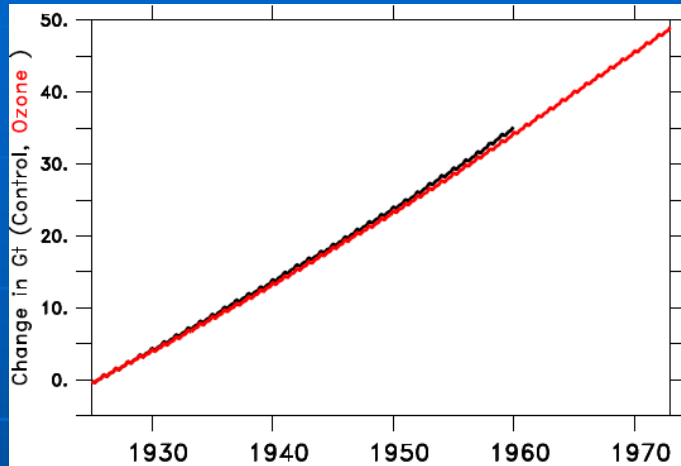
- Global difference several hundred Tmol.
- Large in comparison with natural variability.

Response of remineralized carbon to changing ozone

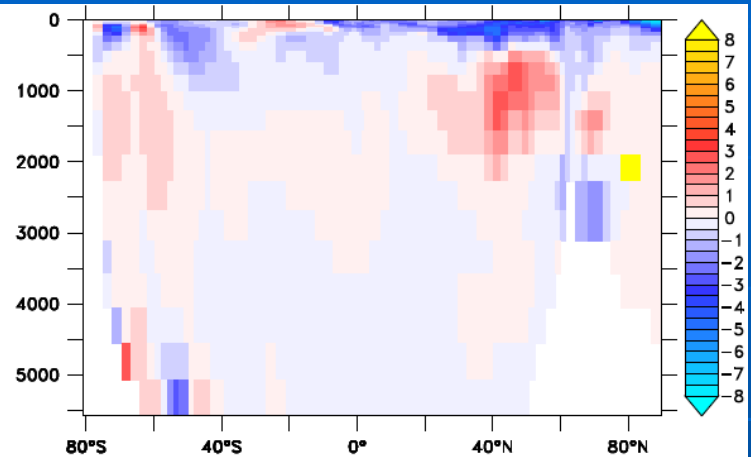


- Global difference a few Gt (about 15%).
- Large in comparison with natural variability.

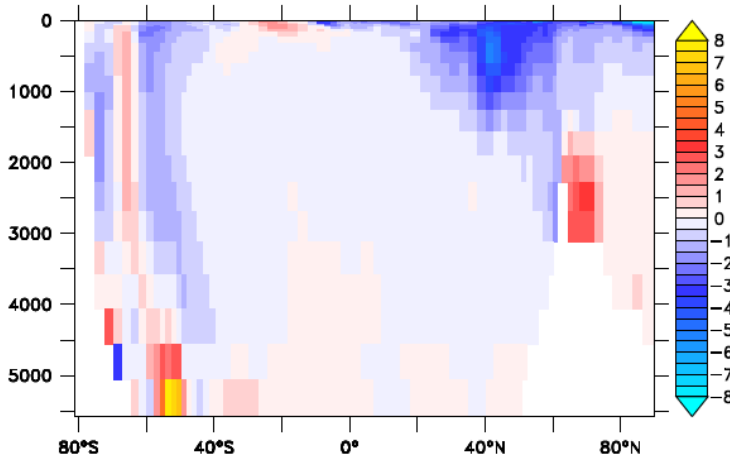
Different behavior of different pumps



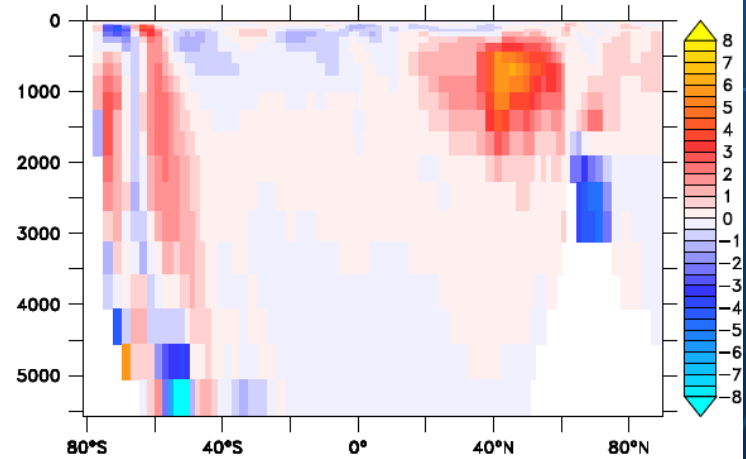
(A) Anthropogenic Carbon Uptake



(B) Zonal Mean Δ DIC

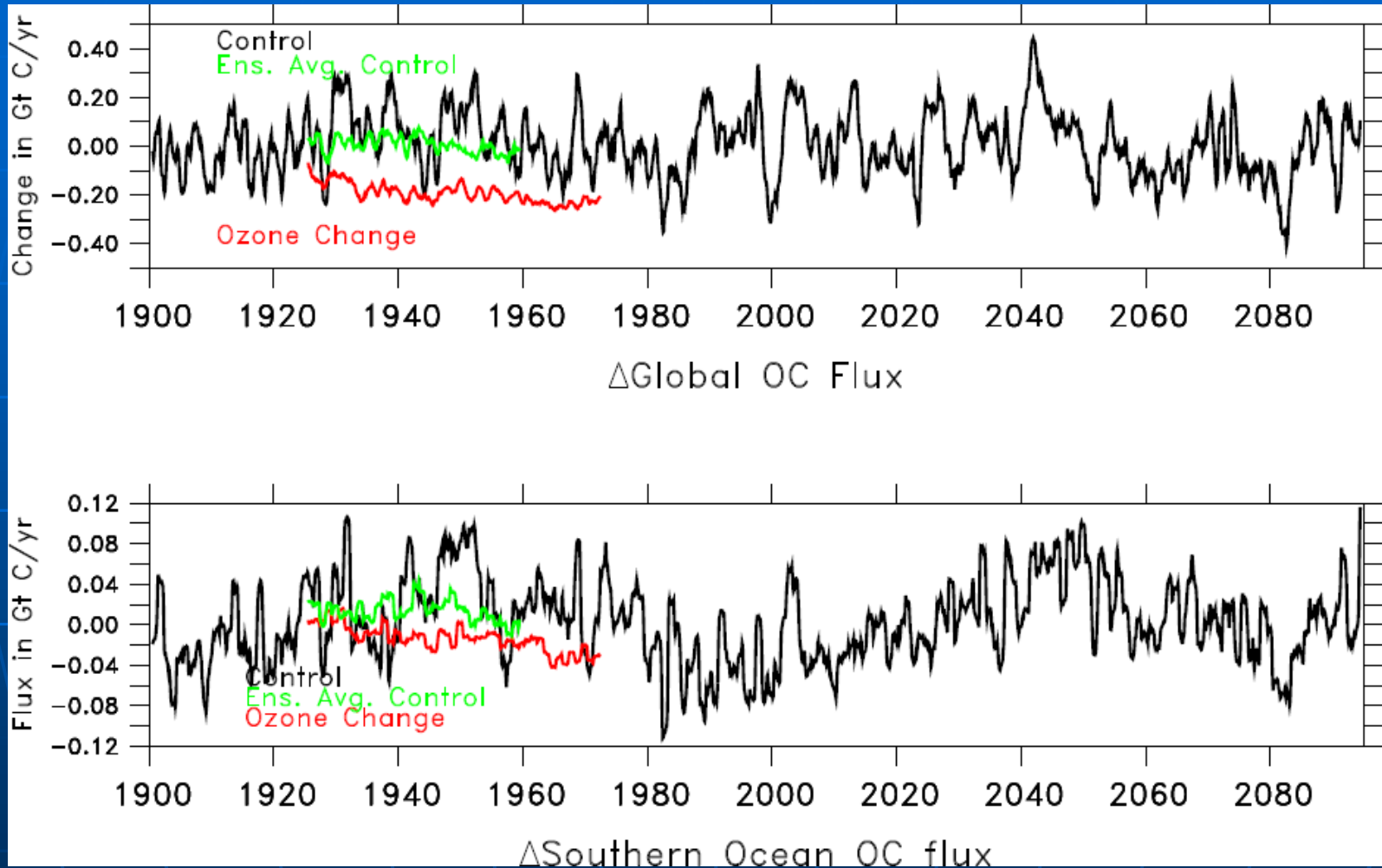


(C) Zonal Mean Δ DIC_{pre}



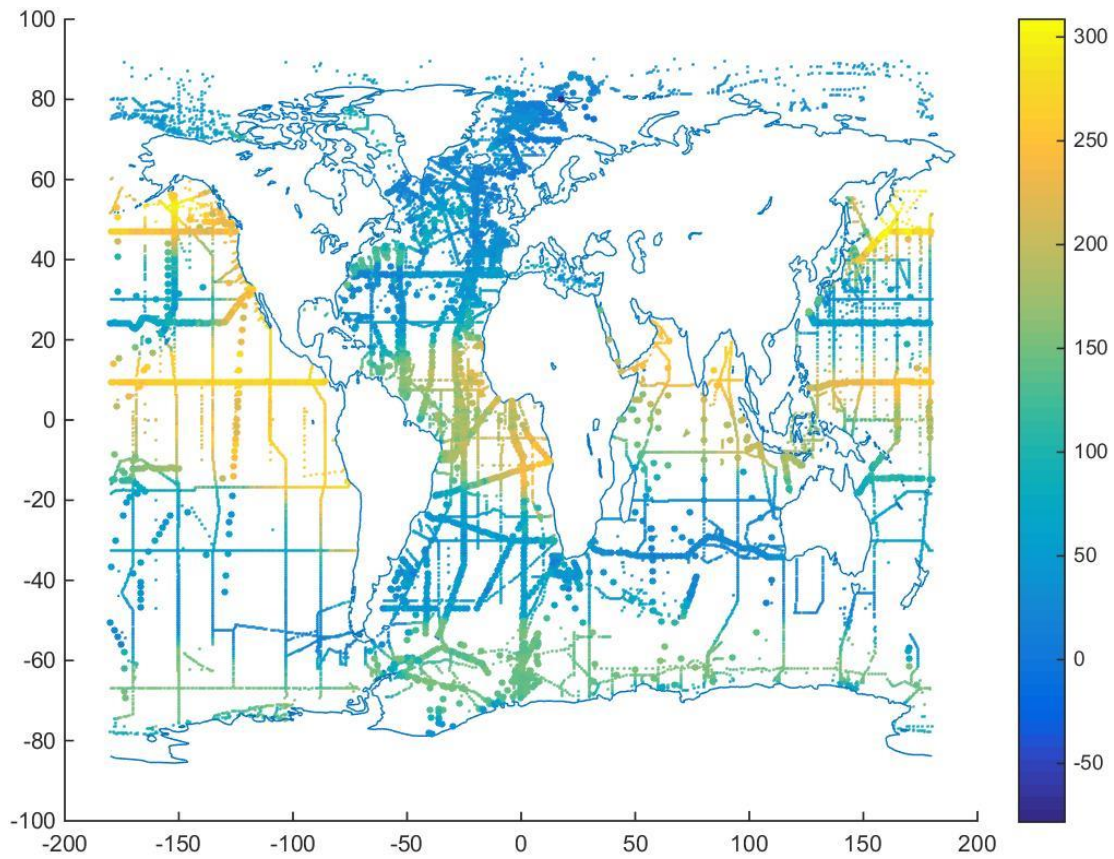
(D) Zonal Mean Δ DIC_{remin}

Particle export to deep



More carbon storage corresponds to lower particle flux...
(but only ~2% of global export)

The challenge



Conclusions-in ESM2Mc

- While ozone has an impact on Southern Ocean carbon uptake...
- Biological and solubility pumps compensate each other...
- Making the size of the change small in comparison with natural variability.
- Observational estimates of Canthro may see a change!!
- Reduction of convection in North Pacific also important...
- But likely driven by tropospheric ozone.
- Oxygen changes more significant.